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 management. Keywords: microsimulation, **pedestrian simulation**, traffic management Main workshop theme: of traffic signals. The traffic and **pedestrian simulation** model is required to represent traffic the average conditions. 3.3 **Pedestrian simulation** Pedestrians follow fixed routes (given as input) on  
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# Pedestrian simulation

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- "The desired speeds within pedestrian crowds are Gaussian distributed with a mean value of about  $1.34 \text{ ms}^{-1}$  and a standard deviation of  $0.26 \text{ ms}^{-1}$ ." -- Helbing, et al "Self-organizing pedestrian movement"

## Papers and Software

- Kardi Teknomo (<http://people.revoledu.com/kardi/>) -- pedestrian simulations
  - Microscopic Pedestrian Simulation Model to Evaluate "Lane Like Segregation" of Pedestrian Crossing (<http://people.revoledu.com/kardi/publication/Kouchi2001.pdf>) (PDF) -- includes excellent formula and diagrams for force-based pedestrian movement
- Panic: A Quantitative Analysis (<http://angel.elte.hu/panic/>) -- Dirk Helbing, Illes J. Farkas, and Tamas Vicsek; simulations and formulas for pedestrians in and leaving enclosed places (rooms)
  - "Simulating dynamical features of escape panic." -- Force-based formula for pedestrians and walls
- Self-organizing pedestrian movement (<http://angel.elte.hu/~fij/homepage/articles/envplanb.pdf>)
- Simulating Urban Crowd Flow (<http://www.csse.uwa.edu.au/~george/crowd/>) -- uses CellularAutomation and PotentialFields
- A microscopic model for simulating mustering and evacuation ... (<http://www.wemt.nl/KNVTS%20paper.pdf>) (PDF) -- uses CellularAutomation and PotentialFields; describes multi-stage movement
- Behavioral dynamics for pedestrians (<http://www.ivt.baug.ethz.ch/allgemein/pdf/bierlaire.pdf>) (PDF) -- describes alternative approaches to pedestrian simulation
- Strolling Down the Avenue with a Few Close Friends (<http://www.cs.uiowa.edu/~kearney/pubs/EurographicsWorkshop02.pdf>) (PDF) -- use control-point following and multiple forces to model one to a few people walking together
- Obstacles in Pedestrian Simulations ([http://e-collection.ethbib.ethz.ch/ecol-pool/dipl/dipl\\_129.pdf](http://e-collection.ethbib.ethz.ch/ecol-pool/dipl/dipl_129.pdf)) (PDF) - detailed math, algorithms, and source discussion
- pedsim (<http://www.twerner42.de/ped/>) -- Torsten Werner; GPL; C++; Linux and Windows; uses Helbing, Farkas, and Vicsek; 2d/3d render; examples are of small areas
- pedsim (<http://pedsim.silmaril.org/>) -- Christian Gloor; GPL; C++; Linux; uses Helbing, Farkas, and Vicsek; 2d and PovRay; examples of very large (10k) crowds and areas
- SimWalk (<http://www.simwalk.ch/>) -- Commercial pedestrian simulation software; for urban planning and evacuation

## Algorithms

A common algorithm for MicroSimulation is to model the forces on the pedestrian: velocity in a direction towards the destination, avoidance of others and walls, gravity, etc.

From "Simulating dynamical features of escape panic" (above):

Each of  $N$  pedestrians  $i$  of mass  $m_i$  likes to move with a certain desired speed  $v_i^0$  in a certain direction  $\mathbf{e}_i^0$ , and therefore tends to correspondingly adapt his or her actual velocity  $\mathbf{V}_i$  with a certain characteristic time  $\tau_i$ . Simultaneously, he or she tries to keep a velocity-dependent distance from other pedestrians  $j$  and walls  $W$ . This can be modelled by 'interaction forces'  $\mathbf{f}_{ij}$  and  $\mathbf{f}_{iW}$ , respectively. In mathematical terms, the change of velocity in time  $t$  is then given by the acceleration equation

$$m_i \frac{d\mathbf{v}_i}{dt} = m_i \frac{v_i^0(\bar{t})\mathbf{e}_i^0(\bar{t}) - \mathbf{v}_i(\bar{t})}{\tau_i} + \sum_{j(\neq i)} \mathbf{f}_{ij} + \sum_W \mathbf{f}_{iW}$$

while the change of position  $\mathbf{r}_i(t)$  is given by the velocity  $\mathbf{v}_i(t) = d\mathbf{r}_i/dt$ . We describe the psychological tendency of two pedestrians  $i$  and  $j$  to stay away from each other by a repulsive interaction force  $A_i \exp[(r_{ij} - d_{ij})/B_i] \mathbf{n}_{ij}$ , where  $A_i$  and  $B_i$  are constants.  $d_{ij} = \|\mathbf{r}_i - \mathbf{r}_j\|$  denotes the distance between the pedestrians' centres of mass, and  $\mathbf{n}_{ij} = (n_{ij}^1, n_{ij}^2) = (\mathbf{r}_i - \mathbf{r}_j)/d_{ij}$  is the normalized vector pointing from pedestrian  $j$  to  $i$ . The pedestrians touch each other if their distance  $d_{ij}$  is smaller than the sum  $r_{ij} = (r_i + r_j)$  of their radii  $r_i$  and  $r_j$ . In this case, we assume two additional forces inspired by granular interactions, which are essential for understanding the particular effects in panicking crowds: a 'body force'  $k(r_{ij} - d_{ij})\mathbf{n}_{ij}$  counteracting body compression and a 'sliding friction force'  $\kappa(r_{ij} - d_{ij})\Delta v_{ij}^t \mathbf{t}_{ij}$  impeding relative tangential motion, if pedestrian  $i$  comes close to  $j$ . Here,  $\mathbf{t}_{ij} = (-n_{ij}^2, n_{ij}^1)$  means the tangential direction and  $\Delta v_{ji}^t = (\mathbf{v}_j - \mathbf{v}_i) \cdot \mathbf{t}_{ij}$  the tangential velocity difference, while  $k$  and  $\kappa$  represent large constants. In summary, we have

$$\mathbf{f}_{ij} = \{A_i \exp[(r_{ij} - d_{ij})/B_i] + kg(r_{ij} - d_{ij})\} \mathbf{n}_{ij} + \kappa g(r_{ij} - d_{ij}) \Delta v_{ji}^t \mathbf{t}_{ij}$$

where the function  $g(x)$  is zero if the pedestrians do not touch each other ( $d_{ij} > r_{ij}$ ), and is otherwise equal to the argument  $x$ .

The interaction with the walls is treated analogously: that is, if  $d_{iW}$  means the distance to the wall  $W$ ,  $\mathbf{n}_{iW}$  denotes the direction perpendicular to it, and  $\mathbf{t}_{iW}$  the direction tangential to it, the corresponding interaction force with the wall is given by

$$\mathbf{f}_{iW} = \{A_i \exp[(r_i - d_{iW})/B_i] + kg(r_i - d_{iW})\} \mathbf{n}_{iW} - \kappa g(r_i - d_{iW}) (\mathbf{v}_i \cdot \mathbf{t}_{iW}) \mathbf{t}_i$$

Constants:

$$m = 80 \text{ kg}$$

$$v_i^0 = 1.34 \text{ m s}^{-1} \text{ mean, with std. dev. of } 0.26 \text{ m s}^{-1}$$

$$\tau_i = 0.5 \text{ s}$$

$$A_i = 2 \times 10^3 \text{ N}$$

$$B_i = 0.8 \text{ m}$$

$$k = 1.2 \times 10^5 \text{ kg m}^{-2}$$

$$\kappa = 1.2 \times 10^5 \text{ kg m}^{-1} \text{ s}^{-1}$$

$$2r_i = \text{uniformly distributed in the interval } [0.5 \text{ m}, 0.7 \text{ m}]$$

The velocity  $v_i^0$  is drawn from "Self-organizing pedestrian movement" as a "normal flow", rather than the higher velocities in the panicking model.

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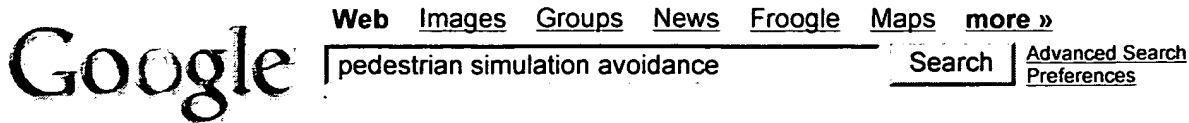
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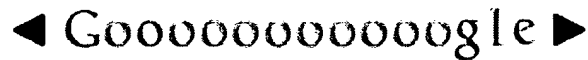
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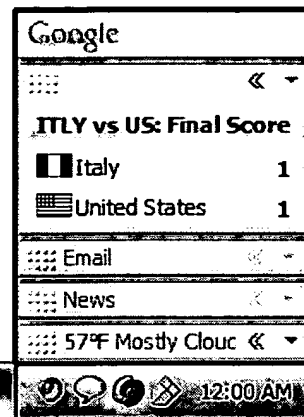
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**Publication:** Lecture Notes in Computer Science  
**Authors:** Katsutoshi Narimatsu, Toshihiko Shiraishi, Shin Morishita  
**Publisher:** Springer Berlin / Heidelberg  
**Issue:** Volume 3305/2004  
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**Publication:** Lecture Notes in Computer Science  
**Authors:** Christian Gloor, Pascal Stucki, Kai Nagel  
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**Issue:** Volume 3305/2004  
**Pages:** 581 - 590  
**Excerpt:** There is considerable interest in the simulation of systems where humans move around, for example for traffic or pedestrian simulations. Multiple models for pedestrian ...

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**3. Monte Carlo Soft Handoff Modeling**  
**Publication:** Lecture Notes in Computer Science  
**Authors:** Alexey S. Rodionov, Hyunseung Choo  
**Publisher:** Springer Berlin / Heidelberg  
**Issue:** Volume 2510/2002  
**Pages:** 560 - 568  
**Excerpt:** In this paper some models for obtaining the distribution of a sojourn time in CDMA cellular systems are proposed. Knowledge on this is essential for reliable modeling of the soft handoff and for solving other related problems in the analysis of cellular systems. The proposed model is based ...

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**4. Crash simulation with glassy polymers — constitutive model and application**  
**Publication:** International Journal of Crashworthiness  
**Authors:** T Pyttel, S Weyer  
**Publisher:** Woodhead Publishing Limited  
**Issue:** Volume 8, Number 5  
**Pages:** 433 - 442



**Excerpt:** During the past two decades explicit Finite Element codes have become an indispensable tool for crashworthiness analysis and the design of passenger safety systems. While these codes are reliable for the prediction of ductile metal structures, there are many open questions for glassy polymers. Glassy ...

5. **Proposal and Evaluation of a System Which Aims Reduction in Unexpected Collision at Non-signal Intersection**

**Publication:** Lecture Notes in Computer Science

**Authors:** Hiromi Kawatsu, Sadao Takaba, Kuniaki Souma

**Publisher:** Springer Berlin / Heidelberg

**Issue:** Volume 3398/2005

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**Excerpt:** Focusing attention to the non-signal intersection in a residential area, a new traffic control system after securing a pedestrians' safety is proposed. Reduction in the unexpected collision accident at the intersection where pedestrians ...

6. **CA Approach to Collective Phenomena in Pedestrian Dynamics**

**Publication:** Lecture Notes in Computer Science

**Authors:** Andreas Schadschneider, Ansgar Kirchner, Katsuhiro Nishinari

**Publisher:** Springer Berlin / Heidelberg

**Issue:** Volume 2493/2002

**Pages:** 239 - 248

**Excerpt:** Pedestrian dynamics exhibits a variety of fascinating and surprising collective phenomena (lane formation, flow oscillations at doors etc.). A 2-dimensional cellular automaton model is presented which is able to reproduce these effects. Inspired by the ...

7. **Monitoring the abundance of mouflon in South France**

**Publication:** European Journal of Wildlife Research

**Authors:** M. Garel, J. -M. Cugnasse, A. Loison, J. -M. Gaillard, C. Vuiton, D. Maillard

**Publisher:** Springer Berlin / Heidelberg

**Issue:** Volume 51, Number 2

**Pages:** 69 - 76

**Excerpt:** Monitoring change in the population size of mouflon (*Ovis gmelini musimon* × *Ovis* sp.) in rugged areas is an important yet difficult task for wildlife ecologists. To assess population change of mouflon inhabiting the Caroux-Espinouse massif, France, we compared a pedestrian ...

8. **Simulating hydrodynamics: A pedestrian model**

**Publication:** Journal of Statistical Physics

**Authors:** Leo P. Kadanoff

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**Publication:** International Journal of Wireless Information Networks

**Authors:** Li Fung Chang, Sirikiat Ariyavisitakul

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**Excerpt:** In recent years, various access technologies have been studied for wireless access to telephone networks and for personal digital radio communications. This paper discusses the performance of a slow-frequency-hopped time-division multiple access (SFH-TDMA)

technique, which can be considered as a "high-tier" ...



10. Pedestrian Modelling: A Comparative Study Using Agent-Based Cellular Automata

**Publication:** Lecture Notes in Computer Science

**Authors:** Nicole Ronald, Michael Kirley

**Publisher:** Springer Berlin / Heidelberg

**Issue:** Volume 3993/2006

**Pages:** 248 - 255

**Excerpt:** In this paper, we examine pedestrian population dynamics using agent-based cellular automata models. Each pedestrian is treated as an agent, mapped onto a 2-dimensional grid. The behaviour of each agent is modelled as a ...

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